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Maine Agricultural Experiment Station

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PLANT-HOUSE ALEYRODES.

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This Bulletin contains a study on the anatomy,
histology, development and habits of the plant-house
Aleyrodes (Aleyrodes vaporariorum) Westw. and sug-
gested remedies for the pest.

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AGRICULTURAL EXPERIMENT STATION
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PLANT-HOUSE ALEYRODES.

Aleyrodes vaporariorum Westw.

Lewis R. Cary.

During the summer this species of Aleyrodes lives chiefly out of doors on garden plants, and in the fall larvæ and pupæ are brought into the greenhouse with the plants, and some of the adults fly in. Here they begin to breed freely as soon as crops are started, multiplying fast enough to keep pace with the growth of the plants. The eggs are very abundant on the under surface of the leaves of various greenhouse plants, frequently occurring in numbers so great that they give the under side of the leaves a decided brown cast.

The curious manner in which the eggs are deposited has been already observed. Mr. W. E. Britton describes the process [*] with reference to Reaumur's observation of the habit in *Aleyrodes chelidonii*. The female inserts her beak into the leaf and with this point as a center she swings about, describing a circle with her ovipositor. The number of eggs in such circles varied in the different instances noted here from six to ten. Much of the time eggs were deposited promiscuously over the leaf. On rough hairy leaves, like those of the Abutilons, the eggs were found without definite arrangement, which agrees with Mr. Davis's observation that on plants like Ageratum the eggs are deposited singly.

[*] Report of the Connecticut Agricultural Experiment Station, 1902, p. 153.

Note. These studies were made by Mr. Cary in 1902-3 in the biological laboratory of the University of Maine, under the direction of Dr. G. A. Drew, professor of biology in the University and at that time zoologist to this station. The station greenhouses have been infested with this species of Aleyrodes for several years and thus afforded ample material for the study. They were most abundant on the leaves of tomatoes and cucumbers, but other kinds of plants were more or less infested.

TECHNIQUE.

The material was fixed with hot water, alcoholic-picro-sulphuric, and alcoholic picro-corrosive acetic. The two latter solutions when used hot gave the best histological results. Some eggs in the earlier stages which were fixed in absolute alcohol gave very satisfactory results. In all cases the material was washed immediately after killing in 70 per cent alcohol.

In studying the different stages as entire transparent objects the best results were obtained by pricking each specimen with a very fine needle, and staining either in Grenacher's borax-carmine or alcoholic cochineal for twenty-four to forty-eight hours. Then the material was washed with 70 per cent alcohol acidulated with a few drops of hydrochloric acid for two or three days, or until it was bleached sufficiently. Xylol was used for the clearing medium as it gave whiter and more transparent mounts than either clove or cedar oil.

In sectioning the younger stages, Dr. Drew's method for orienting small objects was very helpful.* The eggs to be sectioned were stained as for whole mounts, but were not washed out as thoroughly. They were then cleared in clove oil, mounted on the tracing cloth and finally cleared in xylol before transferring them to the paraffin bath. By this method good series of sections were obtained of all the stages. The sections were finally stained on the slide with Mayer's haemalum or iron haematoxylin.

EMBRYOLOGY.

The surface of the eggs is smooth and without any markings. When newly laid they are creamy white or very light green, but in two or three days they become darker, growing almost black before the time of hatching. The color change starts from the pointed end of the egg and extends over the surface. As will be seen from Figs. 41, 44 and 48, the eggs are elongated oval, one side being a little concave. The body of the egg is from .2 to .25 millimeters in length, and from .085 to .1 millimeter in diameter through the thickest part. A short narrow stalk at the

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* Drew, Gilman A. A modification of Patten's method of imbedding small objects for sectioning in definite planes. Zoologischen Anzeiger, Bd. XXIII, No. 611, 1900.

broad end of the egg attaches it to the leaf and serves also as the external part of the micropylar apparatus. The lumen of the stalk is filled with protoplasm, which is in direct communication with a space in the end of the egg containing a mass of granular protoplasm in which the nucleus and polar bodies are situated. This space is separated from the yolk by a distinct membrane. See Fig. 44.

The yolk (Fig. 44) is composed of a great number of small, nearly spherical bodies, each consisting of a vesicle containing a viscid coagulable substance which stains deeply with haematoxylin or carmine. The yolk granules are arranged so that there are many comparatively large spaces which are filled with oily fluid left between them. The oil globules are scattered evenly through the substance of the yolk. Over the whole surface of the yolk the peripheral protoplasmic layer is thin and inconspicuous.

Maturation of the egg takes place within the ovarian tubes of the female. In the mature egg the polar bodies lie in the chamber at the posterior end of the egg which contains the nucleus and undifferentiated protoplasm. The eggs are fertilized in the vagina of the female. The spermatozoon moves up through the protoplasm contained in the stalk of the egg, while the female pronucleus moves down and comes to lie at the entrance of the stalk. Immediately after the act of fertilization, the protoplasmic contents of the stalk shrivel and dry up. When the two pronuclei have fused, the resulting nucleus migrates back to the center of the mass of protoplasm and at once begins active division. The nuclei resulting from the first few divisions begin to migrate toward the periphery of the egg, keeping an arrangement conforming very nearly with the shape of the original protoplasmic vesicle. The wall of the vesicle disappears as the nuclei approach it.

Each of the nuclei resulting from the frequent divisions is surrounded by some of the protoplasm present in the vesicle. As the nuclei migrate farther and farther from their point of origin, it necessarily happens, on account of the location of the parent nucleus, that they first reach the surface of the yolk in the posterior part of the egg. When the nuclei reach the surface of the yolk they begin to arrange themselves regularly in the thin layer of protoplasm there present. The protoplasmic layer

increases in thickness at the time of the arrival of the nuclei. This thickening seems to be due to the taking up of the protoplasm which accompanies the nuclei in their migration through the yolk. As the nuclei increase in number they become crowded and press outward, forming little protuberances on the surface of the egg. Gradually, due to the increase of nuclei within, the outside walls of the protuberances approach each other and finally fuse to form the cell walls of the blastoderm. The inner wall of the cells appears later and seems to be formed by the hardening of protoplasm at that point.

The blastoderm extends rapidly over the surface of the yolk from the point where the nuclei first came to the surface. Before the blastoderm has come to cover the whole surface of the yolk, it has commenced to thicken over a small area on the ventral (concave) surface of the egg, a little in front of the posterior end. This thickening increases in size and forms the embryonic disc. In a short time a slight invagination appears at the centre of the disc. The invagination deepens rapidly and becomes directed toward the anterior end of the egg. The cells of the anterior limb of the invagination increase in length and thickness, while those of the posterior limb become very much flattened. The invagination deepens by the addition of cells at its inner end, and the space between the two limbs of the invagination, the amnionic cavity, becomes reduced to a narrow lumen open to the surface at the point where invagination began. This opening continues to grow smaller as the blastoderm folds approach each other over the point of invagination. See Fig. 47.

During the early part of the first day the folds of the blastoderm now marking the amnion and serosa come together over the mouth of the invagination. The two folds fuse at the point of contact, but the inner and outer layers soon separate from each other. The amnion however continues to remain almost in contact with the serosa so that there are only a few yolk granules between them at any time. The embryo, therefore, is of the superficial type, such as had been described by Metschnikoff* for Corixa.

Sometimes before the closure of the invagination has taken place there begins to be formed on the dorsal side of the germ

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* Metschnikoff E. Untersuchungen über die Embryologie der Hemipteren. Zeits. für Wiss. Zool., Bd. XVI, 1886.

bands a shallow median groove.   Certain cells in the vicinity of
this groove seem to lose their epithelial nature and pass down-
ward until they come to be below the surface layer of cells.   The
cells which go to make up the region of the groove pass down
and out to form a complete layer below the ectoderm.   There is
no distinct separation of a median plate or tube in the formation
of the lower layer.   The anterior end of the germ band becomes
widened out to form the cephalic lobes (Fig. 49).   The germ
band is strongly flexed just posterior to the cephalic region,
so that the cephalic and thoracic regions and are nearly in appo-
sition.   On the dorsal side of the expanded germ there is formed
quite early a slight invagination which marks the beginning of
the stomodæum.   The proctodæum is usually formed a little
later than the stomodæum.

Even before the formation of the lower layer is entirely com-
pleted the germ band begins to show traces of segmentation in
the thoracic and anterior abdominal regions.   Very soon after
the segmentation of the germ band becomes apparent, the first
rudiments of the appendages begin to make their appearance.
The rudiments of the antennae arise first, being situated on the
cephalic lobes just posterior to the region of the stomodæum.
The rudiments of the mouth parts and of the thoracic limbs
appear simultaneously, and those of the abdomen appear suc-
cessively, from before backward, at a little later stage.   The
abdominal rudiments have the form of little conical projections
on the ventral surface of the abdomen.   They persist for a short
time only and, with the exception of perhaps the two posterior
pairs, leave no traces of themselves when they are absorbed.

Tracheal invaginations begin to appear at about the same time
as the limb rudiments.   Eleven pairs of invaginations are
formed ;—a pair on each thoracic segment and a pair on each of
the first eight abdominal segments.   These invaginations, with
the exception of those on the thorax and on the eighth abdominal
segment, disappear during embryonic life.   The four that persist
form the external openings of the tracheal system of the larva.

The nervous system begins to appear simultaneously with the
tracheal system and the abdominal limb rudiments.   The brain
is formed in the cephalic lobes as paired thickenings of the ecto-
derm just anterior to the stomodæum.   The ventral chain of
ganglia are formed as ectodermal thickenings, a pair to each

segment. Those of the four posterior abdominal segments are very small and do not continue to develop.

In the later life of the embryo there is a marked concentration of the ventral nervous system. The ganglia in the abdominal region are reduced to a nerve cord and the ganglionic part of the chain is confined to the thorax. When the lower layer was formed, two masses of cells, one anterior and the other posterior, developed in a manner distinct from that of the great mass of the lower layer. These two cell masses become the rudiments of the developing enteron. As the growth of the embryo goes on they spread farther and farther toward the center of the body forming two u-shaped bands of tissue. Finally the two bands come together and fuse on the ventral side, the dorsal side remaining open until after rotation takes place. While the changes leading to the establishment of these sets of organs are going on, the germ band is increasing rapidly in size, both longitudinally and laterally. The posterior end of the embryo becomes strongly flexed, so that it extends toward the posterior end of the egg and lies along the ventral side of the abdomen. The appendages have increased in length and the mandibles and maxillæ have become lobed.

On the fourth or fifth day after the egg is laid, rotation of the embryo takes place. The amnion and serosa fuse at the point where they previously separated. The fused envelopes are ruptured and the embryo begins to be drawn out through the opening in the membranes. The head of the embryo passes anteriorly along the ventral surface of the egg until it comes to occupy the anterior end of the egg, the posterior part of the embryo taking up its position in the posterior end. By this rotation the embryo has come to a position so that its ventral surface is next to the ventral surface of the egg. The embryonic envelopes, during the process of rotation, are carried around so that they lie as a shrunken mass on the dorsal side of the embryo, making a provisional body wall. The serosal part of the envelope soon becomes a thick mass of cells, with prominent nuclei, situated just posterior to the head, making the dorsal organ. The yolk mass of the egg, which by this time has been much diminished in bulk, is brought so that it lies inside of the body in the region of the growing enteron. The dorsal walls of the enteron now grow rapidly and soon inclose

the yolk substance within the lumen of the gut. The dorsal organ begins to break up, its cells disintegrate, their substance being used for the nourishment of the embryo. The body walls of the embryo grow out laterally and take the place of the amnion as the covering of the dorsal surface. After the dorsal wall of the enteron has closed, a pair of diverticula are given off from it near the anterior end. These increase rapidly in size until they are larger than the original part of the enteron.

Quite late in the embryonic life of the insect there are formed in the thoracic region of the embryo five pairs of imaginal discs, three pairs on the ventral and two pairs on the dorsal side. These discs arise as ingrowths of the hypodermis which soon lose their connection with the outer layer and remain just below the surface as closed pouches of ectoderm. The internal layer of the pouches increases in thickness by the multiplication of the cells, but the outer part remains a single celled layer.

In the latter part of the embryonic development the changes which take place are mostly confined to the readjustment of the organs already present, which gives to the fully formed embryo the proportions seen in the newly hatched larva. These changes are particularly noticeable in the appendages. The larval integument is secreted by the hypodermis. There is an increase in the size of the embryo so great that the egg is distended until it is markedly larger than at the time it was deposited.

On the thirteenth or fourteenth day after the egg is laid the shell splits on the anterior end and the larva appears. The larva when it first comes from the egg is rounded and compressed on account of its having had to conform to the shape of the egg shell. After it is free it soon flattens out and assumes the typical larval form. The larva moves about for a short time after hatching and then settles down to its scale-like immovable existence. After its period of moving is over the legs begin to atrophy and by the time the pupal stage is reached have almost completely disappeared. The mouth parts of the larva consist of a number of piercing setæ which are thrust into the tissues of the leaf, where they remain during the larval stage. The tracheal system shows peculiar adaption to the mode of life which the larva assumes. The body of the larva is in close contact with the surface of the leaf, so that no air could reach it from that

direction. Two special channels for conveying the air to the spiracles, which are situated on the ventral surface of the body, have been developed. These breathing folds are grooves in the integument of the ventral side, one in the thoracic region, the other on the posterior part of the abdomen. The cavity of the breathing folds is supplied with fine chitinous hairs and there are a number of stiffer hairs at the aperture of the fold which serve to prevent the entrance of solid particles. There are four pairs of spiracles, one abdominal and three thoracic, one pair of the latter being situated just posterior to each pair of legs. These spiracles open into a series of projections of the first breathing folds, each fold being divided into three branches at the internal end.

The tracheal system consists of a ventral trunk on either side connecting the spiracles, two dorsal girdles connecting the two anterior pairs of spiracles, and a dorsal trunk on either side extending from the anal spiracles to a point half way between the second and third thoracic spiracles, where it joins the ventral trunks. Branches are given off from the first spiracle as follows. Two main branches, one of which soon divides into a large number of long twigs which spread out to the sides of the body. The other main branch gives off the dorsal girdle, and soon after divides into two about equal branches one of which is the ventral trunk, while the other goes anteriorly. This last trunk divides into two branches, the dorsal branch breaking up into long convoluted tubes which supply the sides of the head, the other goes almost to the mouth opening, where it curves around and breaks up into a number of branches which continue anteriorly to the edge of the body. The trunks from the second pair of spiracles divide into two main branches each of which gives off smaller branches, the upper posteriorly and the lower anteriorly, to supply the surrounding viscera. The main ventral branch goes to the ventral trunk, the dorsal branch forming the dorsal girdle. The third spiracle opens into a trunk which gives rise to an external and an internal branch. The external branch soon separates into an anterior and a posterior division and each of these breaks up into a number of fine branches supplying the body in the metathoracic and anterior abdominal region. The internal branch goes to the ventral trunk. The anal spiracle gives rise to a dorsal and a ventral

branch and a smaller branch laterally.   From the lateral branch
there arises successively a number of twigs going to the sides of
the abdomen.   The ventral branch goes to the ventral longitudi-
nal trunk and the dorsal branch to the dorsal longitudinal trunk.

In the abdominal region of the larva the rudiments of the
reproductive organs appear as a pair of prominent yellowish
organs made up of large cells.   The imaginal discs of the exter-
nal genital organs appear during the larval period as two pairs
of invaginations of the hypodermis at the posterior part of the
abdomen.   The imaginal discs of the hypodermis appear in the
abdomen at about the same time as those of the genital organs.

There are three moults during the larval stage.   The first one
occurs at from five to six days after hatching.   The second
occurs four or five days later, and the third five to six days after
the second.   At each of the moults there is a very appreciable
increase in the size of the larva, but there is no apparent change
other than the growth of the organs and the formation of the
imaginal discs already mentioned, although it is probable that
the imaginal discs of the digestive and other organs are formed
during larval life.   With the occurrence of each moult there is
an increase in the number of the wax rods secreted around the
margin of the body.

In the pupal stage (Fig. 43) which lasts from twelve to sixteen
days, there are many important changes taking place on the inter-
ior.   The whole external form of the insect is changed, from
that of a wingless, motionless larva, to an active flying form.
The greater part of the organs of the larva, with the exception of
the nervous and reproductive systems, are entirely made over to
met the requirements of the new mode of life.   All of the mus-
cles are reduced to an almost structureless condition.   The
greater part of the muscles of the body undergo histolysis at the
same time.   The imaginal discs of the thoracic region become
everted so that they lie outside of the body.   The developing
legs take on their normal appearance, the wings are folded up
in the form of pads on the thoracic tergites.   The external geni-
tal organs are developed from the two pairs of imaginal discs in
the posterior parts of the abdomen.   The central part of the
nervous system passes directly over from the larva to the imago,
but it undergoes farther concentration during the pupal period.

The reproductive organs pass over from the undifferentiated state, and begin to show the characteristics of the male or female organs. The genital ducts, connecting the reproductive organs with the exterior, develop. The larval hypodermis is broken up and the body wall of the adult is formed from the imaginal discs present. The imaginal integument is apparently formed as a secretion from the hypodermis. The escape of the imago from the pupa case is accomplished by the splitting of the case in the mid dorsal line from the anterior end to the region of the thorax.

THE ADULT INSECT.

The adult insect (Fig. 46 and 51) measures 1 to 1.5 millimeters from the head to the end of the folded wings. The males are as a rule smaller than the females, and have more slender bodies. The body is yellowish in color. The wings are pure white and each has a single median vein, which in the fore wings has a branch near the base. The legs are long and slender, and are terminated by a two-jointed tarsus which is furnished with three claws. The eyes are four in number, those on each side of the head situated one above the other with a triangular piece of integument extending between them from the posterior side of the head. Above each eye is an ocellus.

The mouth parts consist of a three-jointed rostrum which arises from the back side of the head, and contains on its anterior side a groove in which are situated four piercing setæ. The setæ have a different point of origin from the rostrum, arising farther forward on the head. The antennæ are seven jointed. The first two segments are short and stout, the remaining five rather long and slender and covered with ring-like markings. The thorax is very deep and its segments short. The thorax and abdomen are connected by a narrow prolongation of the metathorax.

Digestive System. See Fig. 51. The pharnyx, situated at the base of the rostrum, is a narrow tube hardly to be distinguished from the œsophagus, into which it passes with very little change in size. The œsophagus is a long narrow tube extending from the pharynx to the metathorax where it joins the mid-intestine. The mid-intestine runs back to the anterior part of the abdomen where the pair of large diverticula are given off.

From this point it passes posteriorly to the sixth abdominal seg-
ment where it turns and runs anteriorly again to the first abdom-
inal segment; here it turns about again and joins the hind-intes-
tine which runs posteriorly to open on the dorsal surface of the
eighth abdominal segment at the vasiform orifice.   The salivary
glands are small, nearly spherical organs, located in the dorsal
part of the prothorax.   They are made up of a small number of
large secreting cells.   Coming from each gland is a small duct
which unites with its fellow just posterior to the brain in the
median line.

Muscular System.   See Fig. 51.   The muscles of the body are
arranged in three chief systems.   First : the intersegmental mus-
cles running between the segments for the whole length of the
body.   These muscles are attached to the folds of the integu-
ment at the joints between the segments.   Second : the muscles
of the wings, which are arranged in two sets, the elevators and
the depressors.   The elevators are attached at their ventral ends
to ridges on the integument of the ventral wall of the two poste-
rior thoracic segments, and at their dorsal ends to the wings.
The depressors of the wings are two large muscles situated
in the dorsal part of the thorax, attached to the lateral and
dorsal walls of the thorax, and to a deep median ventral pro-
longation of the dorsal integument of the thorax.   Third : the
muscles of the legs.   These muscles are in part attached at the
dorsal ends to the dorsal wall of their respective segments, and in
part to the ventral median ridge.   The ventral ends of both sets of
muscles are inserted in the walls of the femur of the leg to which
they are attached.   There is a small set of muscles for moving
the mouth parts, which are attached dorsally to the dorsal and
lateral walls of the head and prothorax.   In the posterior end of
the abdomen there is a set of small muscles which move the
ovipositor.

Nervous System.   See Fig. 51.   The nervous system is very
much concentrated.   It consists of the brain and a ventral
ganglionic mass.   The brain is quite complicated although of
rather small size.   The *cerebral hemispheres* are very promi-
nent, standing above the other positions of the brain.   The optic
lobes are small, hidden beneath the cerebal portion of the brain.
The optic tracts are well developed.   They appear as a pair of

rounded bodies just posterior to the cerebral hemispheres. The ventral nerve chain consists of a ganglionic mass separated into two parts by a narrow constriction. The anterior mass is small and closely united with the brain, the circum-œsophageal commissures being very broad and the aperture through which the œsophagus passes far back. The second ventral ganglion is large and lies entirely within the mesothorax. It gives off the nerves to the all the legs, and smaller branches to the organs of the thorax. Structurely it is for the most part made up of nerve cells, the amount of fibres being comparatively small. From the posterior end of the second ventral ganglion a large nerve cord passes posteriorly to the abdomen, giving off nerves to the organs in each of the segments through which it passes. It breaks up into a number of fibres in the seventh abdominal segment, the resulting fibres supplying the two posterior segments of the abdomen.

Reproductive System. The reproductive system of the female insect (Fig. 51) consists of two ovaries, each made up of five chambered ovarian tubes. The ovaries are large, extending from the eighth abdominal segment to the anterior part of the abdomen, filling the greater part of the abdominal cavity. The vagina occupies the posterior part of the seventh and the whole of the eighth abdominal segments. The seminal receptacle is situated on the ventral side of the vagina in the eighth segment. The oviduct opens to the exterior at the posterior end of the abdomen between the valves of the ovipositor. The ovipositor, is short, made up of two valves which are deeply concave on the inner side.

The male reproductive organs (Fig. 50) consist of the testes, two rounded bodies situated dorsally in the fifth abdominal segment, one on either side. Coming from the testes the vasa deferentia make a complete turn and are then enlarged to form the seminal vesicles. The two vasa deferentia unite in the seventh segment to form a single tube which extends to the end of the abdomen. At the point where the two vasa deferentia are united they are joined by the ducts from the two large accessory glands. The external genitals of the male consists of the penis and a pair of well developed claspers.

Respiratory System. The respiratory system of the adult insect corresponds in arrangement very closely to that of the

larva. There are four pairs of stigmata, three on the thoracic region and one on the eighth abdominal segment. The stigmata of each side are connected by a ventral trunk, but the dorsal girdles are not complete. The dorsal longitudinal trunk is not complete in the imago, but long branches extend anteriorly from the anal spiracles, and posteriorly from the thoracic spiracles, on the dorsal side of the body.

REMEDIES.

The experience at this Station in destroying the plant-house Aleyrodes is similar to that at the Connecticut Station and the following from their report* will serve to express the situation here.

"Spraying.—In 1895 the writer (Mr. W. E. Britton) used whale-oil soap solution (1 pound of soap to 5 gallons of water) in the form of a spray on the under surface of the leaves to kill the nymphs. The result was successful, but on account of the disagreeable odor of whale-oil soap, it was discarded. Fir-tree oil (one-half pint in 2 gallons of water) gave excellent results when the plants were thoroughly sprayed with the solution. The adults and nymphs which were moistened by the spray were killed. The cost of the material, however, makes the treatment an expensive one and precludes its use on a large scale. Fir-tree oil has a pleasant odor and is not objectionable to use in a green-house of ornamental plants or even in a dwelling.

"A fine spray of kerosene and water (15 per cent. kerosene) was then applied to the tomato plants on sunny days, by means of a 'kerowater' pump, with good results in killing the insects. But kerosene, like whale-oil soap, has an unpleasant odor, and occasionally causes a slight injury to the foliage. Even when not at first apparent, the leaves in some instances took on later a brown or reddish color not indicative of health, and some of these finally dropped.

"Early in 1901, we began spraying the tomato plants with common soap and water, dissolving one pound of soap in eight gallons of water. This seemed to be best, all things considered, of any of the sprays. Not only was it effectual in killing all adults and nymphs with which it came in contact, but it was

* Report of the Connecticut Agricultural Experiment Station for 1902.

both inexpensive and inodorous, and at first did not appear to cause the slightest injury to the plants. The soap was cut in thin slices, then dissolved in hot water, and cold water added to make the right proportions. The plants received one application each week for about three months, when some of the leaves finally exhibited signs of injury.

"As the plants had never been sprinkled with water from the hose and had received frequent applications of soap, the leaves finally became coated over with soap to such an extent as to interfere seriously with the normal processes of respiration. The lower leaves in some cases shriveled and dropped. A few sprayings cause no injury, and probably none would be done in any case if the plants are sprinkled freely with water to remove the excess of soap.

"The chief difficulty with sprays of any kind is that it is impossible to reach all places where the insects are located. Many leaves are curled so that the spray cannot reach the under side, and there are always portions of the plants which do not, on account of location perhaps, receive a thorough treatment; this permits the escape of a sufficient number of adults, or of nymphs which soon change to adults, to keep the house infected.

"Fumigating.—Fumigating with tobacco is the remedy that has been oftenest recommended for this insect, but the fumes from the burning of ordinary stems or dust do not kill any considerable number of the insects. Many are stupefied by the fumes and fall from the plants, but revive later and soon become as active as ever. During the past two or three years tobacco used in this way seems to have been less effective in destroying the adults than when the writer first employed it eight years ago. Where the adults are stupefied and fall to the ground a copious watering of the surface of the soil will kill them in great numbers."

At this Station fumigation with hydrocyanic acid gas is the most successful remedy tried. The gas was made with a half more strong sulphuric acid (liquid measure) than the weight of cyanide, and a half more water than acid. The jar containing the dilute acid was placed on the floor of the house, and the cyanide of potassium which had been put into a paper bag, weighed, and suspended over the jar, was dropped into the acid. This treatment is in accordance with the suggestions by John-

son*. The house was then closed and left, in various experiments, from forty-five minutes to fourteen hours. When the fumigation was given early in the afternoon of a bright day, the tomato plants were injured by the use of one ounce cyanide to 1000 cu. ft. of space. The same amount caused no trouble, however, when the fumigation was postponed until evening, a fact which verifies Johnson's statement†. With 1 oz. cyanide to 1500 cu. ft. of space the plants were not injured. In no case, however, is it considered advisable to fumigate when the sun is shining brightly, or when the temperature is above sixty degrees.

* Johnson, fumigation methods, pages 9 and 118.
† Ibid, 145.

EXPLANATION OF FIGURES.

Fig. 41. Egg. x130.

Fig. 42. Newly hatched larva from the ventral side. x130.

Fig. 43. Pupa from the dorsal side. x130.

Fig. 44. Longitudinal section of a mature egg in the ovary of the female. x530.

Fig. 45. Longitudinal section of an egg when the invagination of the germ band has begun. x530.

Fig. 46. Adult female from the left side. x130.

Fig. 47. Side view of egg with embryo, just before closure of amnionic cavity.

Fig. 48. Reconstruction of a fully developed embryo just before hatching.

Fig. 49. Ventral view of the germ band after segmentation has begun. x530.

Fig. 50. Male reproductive organs seen from above. x130.

Fig. 51. Reconstruction of an adult female shown with the dorsal part of the body wall removed. x130.

REFERENCE LETTERS AND NUMBERS.

a   anterior.
ab   abdomen.
abp   abdominal portion of germ band.
acg   accessory glands.
am   amnion.
amc   amnionic cavity.
an   antenna.
bl   blastoderm.
br   brain.
c   cephalic end of germ band.
cl   cephalic lobes.
cae   diverticulæ of mid intestine.
d   dorsal.
ei   eye.
fw   fore wing.
hd   head.
hi   hind intestine.
hw   hind wings.
idro   rudiments of reproductive organs.
idw1   imaginal disc of fore wing.
idw2   imaginal disc of hind wing.
ism   intersegmental muscles.
lm   muscles of the legs.
mc   male claspers.
mi   mid intestine.
mp   mouth parts.
msth   mesothorax.
mtth   metathorax.
myc   micropyle.

nl   nerves of the legs.
nu   nucleus.
oes   œsophagus.
ov   ovary.
ovd   oviduct.
ovp   ovipositor.
p   posterior.
pas   posterior abdominal segment.
pb   polar bodies.
pe   penis.
prth   prothorax.
sd   duct of salivary gland.
se   serosa.
sg   salivary glands.
stk   stalk of egg.
te   testis.
th   thorax.
v   ventral.
vd   vas deferens.
vg   ventral ganglia.
vg 1   first ventral ganglion.
vg 2   second ventral ganglion.
vg 3   third ventral ganglion.
vnc   ventral nerve cord.
vo   vasiform orifice.
wm   wing muscles.
yk   yolk.
1   fore leg.
2   middle leg.
3   hind leg.

Figure 41.
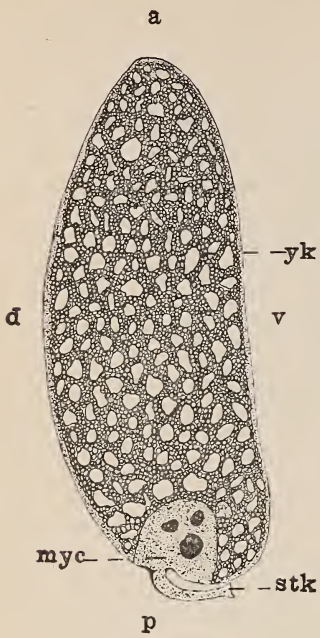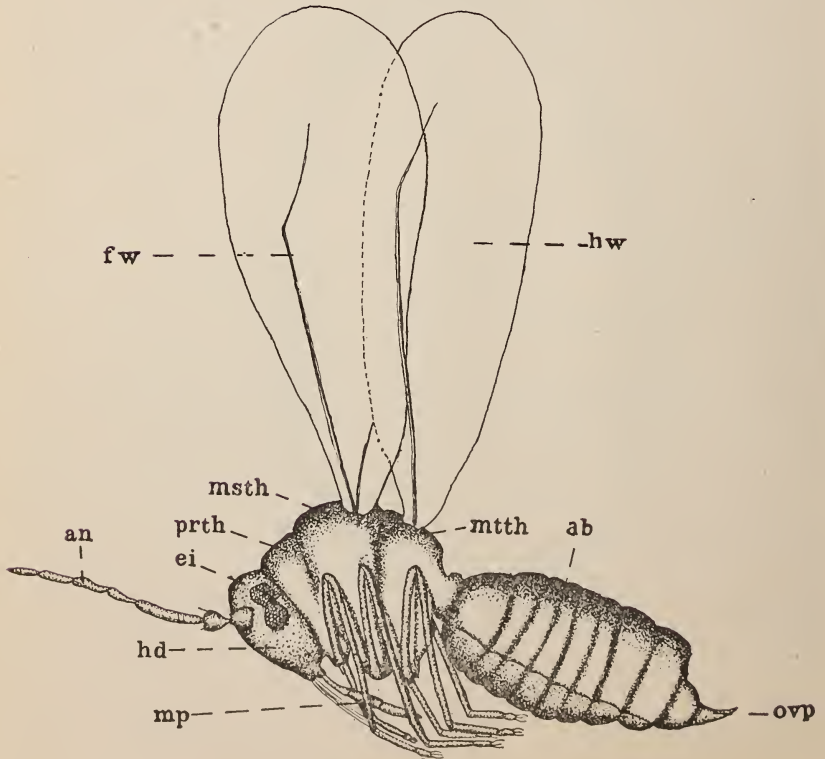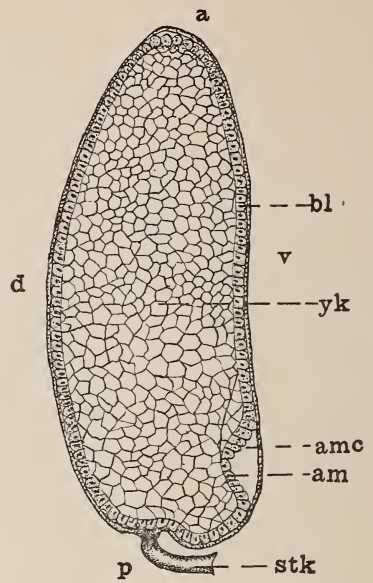
Figure 42.
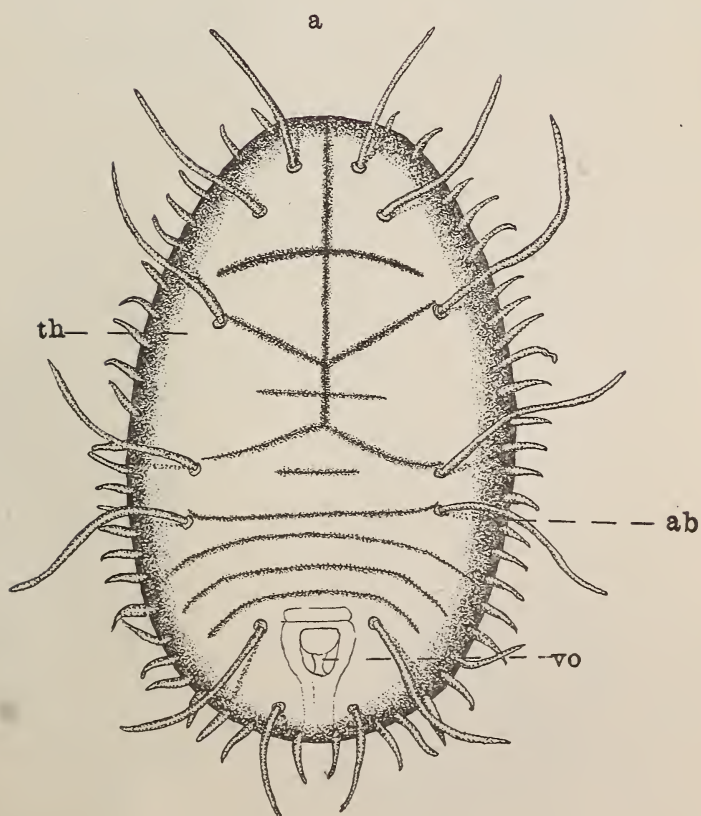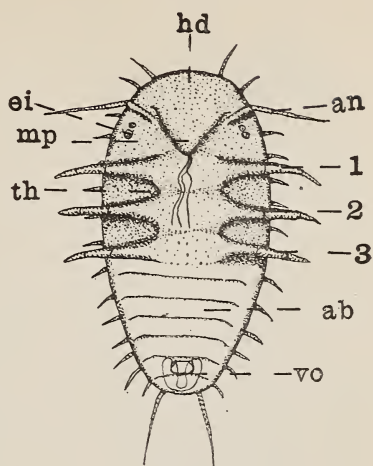
Figure 43.

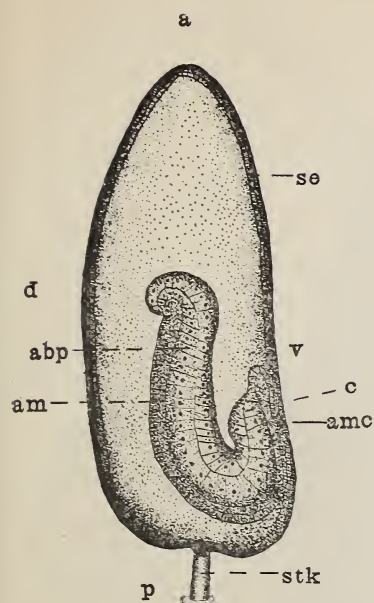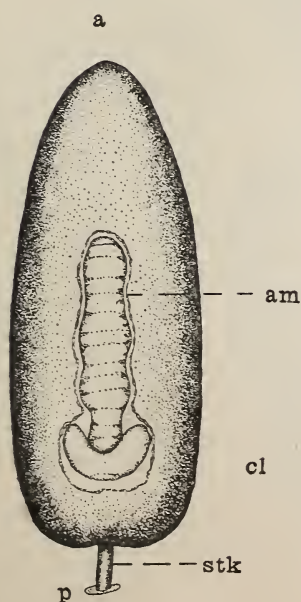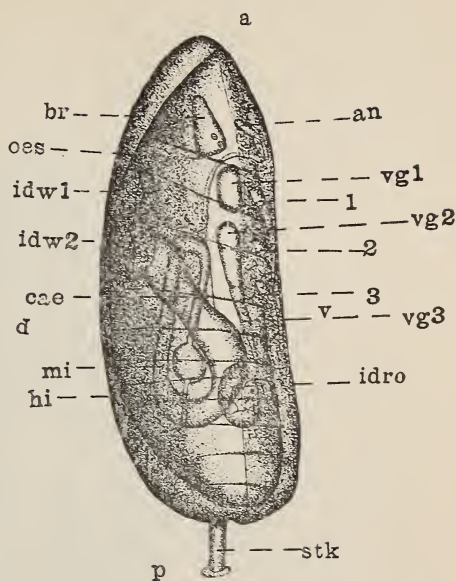Figure 44.   Figure 45.

Figure 46.

Figure 47.

Figure 48.

Figure 49.

Figure 50.

Figure 51.